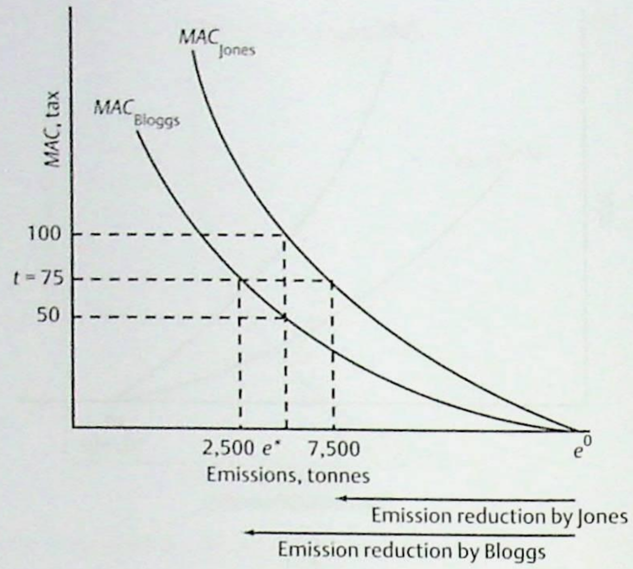

Figure 2.4 Pollution taxes as the least-cost solution.

for each firm. This means that for Jones and Bloggs, the tax produces the following outcome:

$$t = MAC_{\text{Jones}} = MAC_{\text{Bloggs}}.$$

This is the *least-cost solution*, which minimizes the cost of achieving the target reduction. That is important: it implies that taxes can satisfy the efficiency criterion. Why is it the least-cost solution? Because if the marginal abatement costs of each firm were not equal, society could always save money by reallocating emission control responsibility away from the higher-*MAC* firm and towards the lower-*MAC* firm. For example, in Figure 2.4, suppose that the EPA imposed a performance standard equal to e^* on each firm. This means that Jones has marginal costs of £100/tonne at this point, and Bloggs has marginal costs of £50/tonne. If we allowed Jones to increase emissions by one tonne and persuaded Bloggs to cut emissions by one tonne more, total emissions would be unchanged, but we would have saved (100 − 50) = £50. Such gains can be made whenever marginal abatement costs are not equal. But how could Bloggs be persuaded to cut emissions by more than Jones?—By setting the tax of $t = 75$. This gives the desired reduction in emissions (Jones emits 7,500 and Bloggs 2,500, so that new emissions are 10,000 tonnes), but at the lowest cost, since the tax results in marginal abatement costs being equalized.

The least-cost property of pollution taxes (also known as the static efficiency property) is their most important attribute, and it was first set down by Baumol and Oates in 1971 (see their 1988 book). Pollution taxes have one other major advantage. Since each unit of emissions now costs the firm money in tax payments, firms have more incentive to invest in cleaner, greener technology than under regulation. This is known as the 'dynamic efficiency' property of taxes, and has been argued by some to be their most important feature in the long run. What are the problems with pollution taxes as a policy solution?

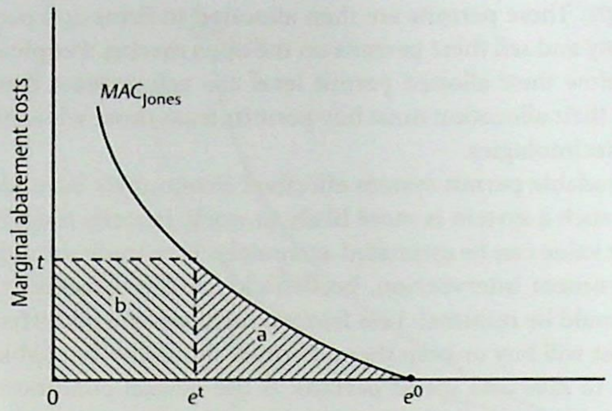

Figure 2.5 The impact of a water pollution tax.

- When pollutants are non-uniformly mixed, then a single tax rate is not efficient. This happens because the tax is levied on emissions rather than on their environmental impact. Firms that cause more damage per unit of emissions should be taxed at a higher rate than firms that cause lower per-unit-of-emission damage. At the limit, correcting this problem involves a unique tax rate for each firm. More pragmatically, suggestions have been made for banded tax rates to try to control for non-uniform mixing to at least some degree.
- Taxes minimize the total abatement costs of hitting the target from society's point of view. But taxes can be more expensive than regulation for firms themselves. This is because firms pay for both abatement and the pollution tax on their remaining emissions. This tax payment could be greater than the abatement costs, and can result in the total financial burden of taxes (areas 'a' + 'b' in Figure 2.5) exceeding that under regulation. This aspect of pollution taxes has, unsurprisingly, resulted in industry lobbying against their wider use.
- The EPA has insufficient information with which to set the tax rate correctly. Additionally, these taxes have to be updated based on new information; for example, as firms' abatement costs change. This makes the uncertainty problem more serious, since it means that the EPA has to keep on re-guessing what the tax rate should be.

Set the quantity of social damages—tradable pollution permit systems, or cap-and-trade. An alternative to a fixed tax is a fixed quantity of pollution that can be traded in a market. Pollution permit markets work by assigning the property rights to pollute to firms, governments, and people (see Gayer, 2008). These rights create and add value to something that was otherwise a free good; for example, clean air or water. This tradable permits, or cap-and-trade, system was first introduced by Professors Thomas Crocker and J. Dales in the mid-1960s. The idea was controversial then because many people did not think that we should 'put a price' on nature. Today, many environmental groups promote the idea of cap-and-trade as the most cost-effective way to protect nature.

Tradable permits focus on the quantity side of the market equation. A regulator selects a fixed quantity of pollution or development, and then sets the number of permits available for trade accordingly. These permits are then allocated to firms and people in the affected area. People then buy and sell these permits on the open market. People who keep pollution or development below their allotted permit level can sell or lease their surplus permits. People who exceed their allocation must buy permits from those who either produce less or find less-polluting technologies.

What makes a tradable permit system effective? Economists have identified the conditions under which such a system is more likely to work. Permits must be well defined and scarce, so that their value can be estimated accurately. Free trade should dominate the permit market. Government intervention, bottlenecks, and transaction costs that limit the scope of trading should be minimal. Less friction increases the odds that people who value the permits the most will buy or keep them. Permits should be 'bankable', such that people have the flexibility to save and spend permits as the market conditions fluctuate. People should be allowed to keep any profits they earn from the trade of permits. The penalties for violating a permit must exceed the permit price, to help make sure people play by the rules.

Again consider the case of Riley and Ole. With a tradable permit system, the regulator selects the amount of ridge development allowable in the valley: development quotas are selected at the socially efficient level, in which marginal benefits equal marginal cost. The regulator allocates permits to the Centennial community based on some predetermined rule—perhaps the number of acres or years spent in the valley. The permits are then free to be traded. If Riley wants to develop open space by building on the ridgeline, he can buy more development permits on the open market. In theory, the equilibrium permit price equates the marginal costs to the marginal benefits of development. Again, the efficient outcome is achieved.

To see how this works, consider our example of a pollution tax. The EPA faced a situation in which two firms emitted a total of 20,000 tonnes of BOD per week, whereas the target level of emissions was only 10,000 tonnes. Instead of imposing a tax, the EPA could have created 10,000 emission permits and allowed firms to trade them between themselves. Because it would be illegal to emit beyond one's permit holding, the target emissions reduction would be reached: with 10,000 permits available, 10,000 tonnes of BOD could be legally discharged in total.

What advantages do tradable permit systems possess? In Figure 2.6, the *MAC* curves for Jones and Bloggs are shown again. Suppose that each firm is given 5,000 permits. Both must cut emissions because their unregulated level is 10,000 tonnes, but by how much? Imagine that, at first, neither firm is willing to trade permits. At an emission level of 5,000 tonnes, Jones faces marginal costs of 100, and so could save this amount if it could increase its emissions by one tonne. That would involve buying a permit from Bloggs, who would have to be willing to sell. Bloggs might sell provided that the permit price was greater than its cost of reducing emissions. The cost to Bloggs of this sale is 50 (its marginal abatement cost at this level of emission): the minimum Bloggs would take is less than the most Jones will offer—a deal can be done. Both Jones and Bloggs gain from this trade. If the permit was to change hands for a price of £80, both would be better off. If all such gains from trade can be captured, we expect trading to continue until the *MACs* are equalized across sources in a competitive market for permits. This idea of trading until we 'equalize *MACs*' is a necessary condition for the cost-minimizing outcome: tradable permits, like taxes, can offer a least-cost way of controlling pollution.

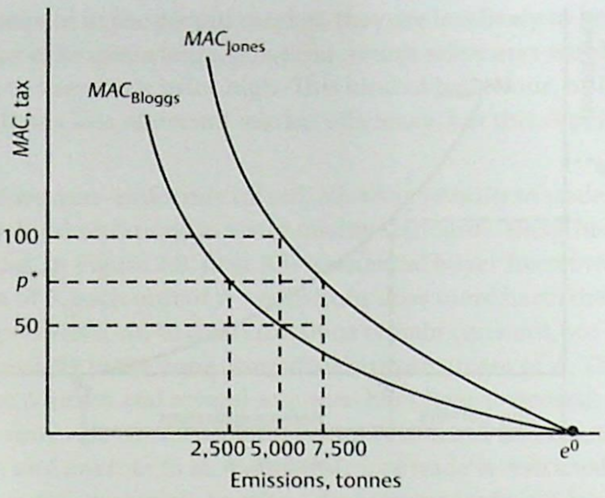

Figure 2.6 Tradable permits as the least-cost solution.

Another way of thinking about trading permits is to consider how a firm would react if offered permits for sale at some fixed price, such as p^* in Figure 2.7(a). Jones would choose to buy e^* permits at this price, which necessitates a cut in emissions from e^0 to e^*. Why? Because if Jones were to buy more permits, they would have spent more on permits, at the margin, than it would cost to abate. If they were to buy less than e^*, they would have spent too little on permits given the cost of abatement. The optimal amount to purchase is the level at which marginal costs intersects with marginal benefits, e^*: Jones should purchase permits until the price exceeds the benefits. If the permit price were to increase, the firm would choose to buy less, and would have to spend more on emissions control (e.g. at p^{**}). If the price fell, they would buy more permits and spend less on pollution control. The firm's *MAC* curve is its demand curve for permits.

Where does this permit price come from? One way to think about this is as the interaction of supply and demand in the permit market. Supply is determined by the number of permits available in total, and that is determined by the EPA when it sets the maximum desired level of emissions, E^* in Figure 2.7(b). The supply curve S is vertical at this point, since no more permits are available from the EPA, irrespective of the price. MAC_I is the aggregate marginal abatement cost curve: its shows the market demand for permits. At E^*, supply and demand are equal at price p^*, and this is the market clearing permit price. If all firms behave as Jones, in a multi-firm market with many dischargers (firms a, b, c, ...), we end up with the situation that

$$MAC(a) = MAC(b) = MAC(c) = ...p^*,$$

which is the same efficient outcome as with a tax.

In practice, permit trading can take place in two ways. First, the EPA may decide to launch the permit market by auctioning permits. All firms bid for permits from a single seller. Once firms have acquired their initial holding, they can trade with each other as their circumstances change or as firms enter and leave the industry/area. In this case, the permit price depends on the bargains that firms strike with each other.

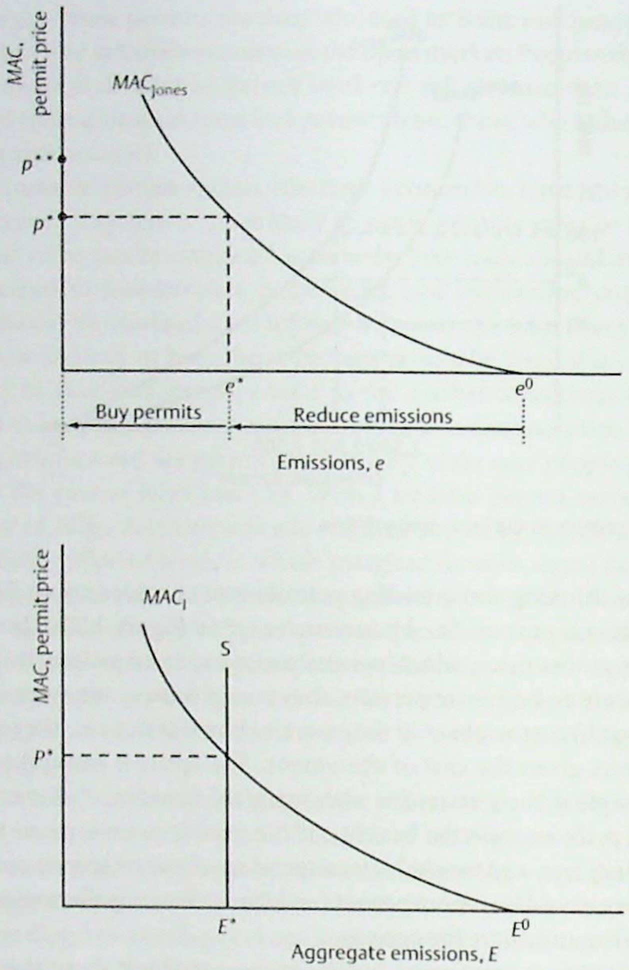

Figure 2.7 Prices in the permit market (a) individual (b) aggregate.

Second, the EPA could give permits away, a practice known as 'grandfathering'. All trades will be inter-firm, unless environmental groups buy permits and then withhold them from the market (to reduce the maximum legal level of emissions). Firms prefer grandfathering to auctioning, since the financial burden is less on average. As with taxes, this financial burden has two parts: the resource costs of pollution abatement, and payments (net of receipts) for permits.

We have seen that permits can generate a least-cost, efficient means of controlling pollution. So what is the catch?

- Transaction costs imply that fewer trades take place than needed to realize all potential abatement cost-savings. The transaction costs are the costs associated with finding potential buyers/sellers, and with negotiating subsequent trades. Evidence from the sulphur-trading programme in the USA suggests that these can be a high percentage of the gains from trade.

- If few firms participate in the permit market, they are less likely to behave competitively. For example, a large, powerful permit seller may withhold some permits from the market to keep their price high. This kind of behaviour, by both buyers and/or sellers, may result in a loss of permit market efficiency, but this depends on the precise circumstances.
- When pollutants are non-uniformly mixed, allowing permits to trade at a one-for-one rate may result in local violations in water quality standards. Imagine that two firms are thinking of trading. In Figure 2.8, firm A is a potential buyer from firm B. Because A is located upstream of B, each unit of A's emissions does more harm than each unit from B. If A buys 100 permits from B, total emissions remain constant, but environmental damage rises, especially in the zone immediately downstream of A. This situation arises in water pollution control, and several solutions have been proposed. One is zonal trading—here, a zone rule would prohibit trades between A and B, and would allow trades between A and another firm, C. But the more trade is restricted in this way, the lower is the cost-saving potential. Another idea is to use trading rules, which would restrict the rate at which A and B can trade. Suppose that A's emissions are twice as harmful per unit as B's in terms of average water quality. The regulator could impose an exchange rate of 0.5/1 per trade between the two. Under this scheme, exchange rates are calculated for all firms on the river, which is possible given current water quality models. In reality, however, one of the largest actual Tradable Pollution Permit (TPP) systems in use, sulphur trading in the USA, does not address the fact that SO_2 is a non-uniformly mixed pollutant, and allows emission-based trades to go ahead at a one-for-one rate.
- Existing firms may use permits as a barrier to entry, to keep out new firms who want to set up.

None of these criticisms means that *all* of the cost-saving potential of TPPs is lost. We would expect some cost savings if a change were to be made from regulation to trading. Relative to pollution taxes, TPPs possess some advantages too. Most importantly, the EPA does not need to know the firms' *MAC* curves to set the system up. All it does is decide how many permits to issue, and what restrictions—if any—to place on trade, and then police the system. Firms may also prefer trading to pollution taxes if permits are allocated free of charge (grandfathered) rather than auctioned. Financial burdens are lower than with an

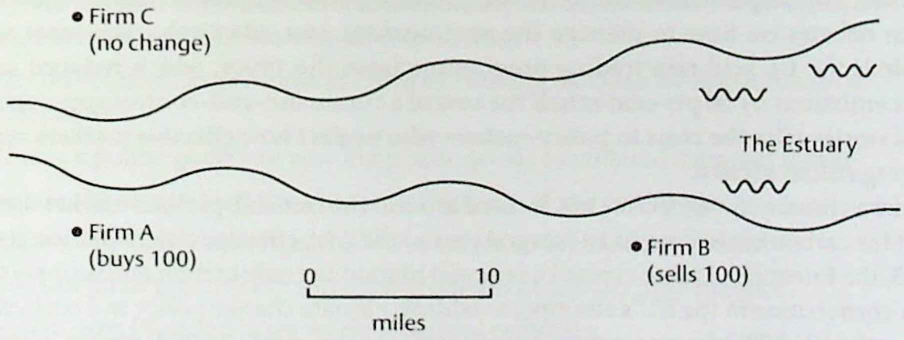

Figure 2.8 Permit trading in an estuary.

BOX 2.5 Trading Pollution Permits: What's the Evidence?

Up until the introduction of the European Union's carbon cap-and-trade scheme, the USA had the most extensive experience of using tradable permit markets to control pollution. The initial moves towards use of TPPs came in the 1970s, due to conflicts between achieving national targets for clean air and allowing economic growth in industrialized states that were in violation of these national targets. Policy initiatives such as offsets, netting, and banking were brought together under the Emissions Trading Program in 1986. This allowed for limited permit trading in 'emission credits' for seven pollutants in 247 control regions across the USA.

In 1992, amendments to the Clean Air Act paved the way for a nationwide cap-and-trade system for sulphur dioxide emissions from power stations. The aim was to reduce total emissions to 50 per cent of existing levels. The market began in 1995. Some 110 of the largest power stations were allocated permits based on historical emissions, and then allowed to trade. Even though SO_2 is a non-uniformly mixed pollutant, permits traded at a one-for-one rate. In 2000, 800 additional power stations were to be brought into the scheme.

Evidence suggests that the pollution permit markets have performed well. First, total emissions fell by more than the target level in phase 1, as firms banked permits for future use. The market in permits grew steadily, and permits prices fell from an initial high of around $1,000/tonne to around $100/tonne. The increasing volume of trading, which reduced transaction costs, and falling abatement costs caused this price fall. This last factor was due to suppliers of abatement equipment cutting their prices, since firms now had an alternative (buying permits), and by reductions in the price of low-sulphur coal due to deregulation.

Overall, the cost savings of the sulphur trading programme have been estimated at up to 50 per cent of what the costs would had been if regulation had been employed instead. This implies a saving to the US economy of nearly $1 billion per year (Carlson et al., 2000). Finally, the total costs of the scheme seem to be less than the benefits, which include the economic value of avoided damage to human health, ecosystems, and recreational activities. Tradable permits have provided good value for the money.

emission tax system. TPP mechanisms also do not need updating if firms' abatement costs shift, since this changes the demand for permits: actual emissions cannot rise above the maximum permitted (see also Box 2.5).

Whether tradable permit markets can flourish as a tool to manage environmental and health dilemmas will be determined over time. Conceived in the 1960s, tested in the 1970s and 1980s, and implemented in the 1990s, tradable pollution permits are now commonplace in debates on how to manage the environment cost-effectively. The most studied example is the US acid rain trading programme from the 1990s, which reduced sulphur dioxide emissions by 50 per cent at half the cost of a command-and-control approach. Such success stories raise the costs to policy-makers who neglect how effective markets can be at managing risk to society.

Modern climate change policy has focused around the tradable permits market that is the market for carbon emissions, as an integral part of the cost-effective risk reduction strategy. In 2005, the European Union created a regional market to trade carbon emissions—the EU ETS. A cornerstone in the EU's attempts to address climate change policy in a cost-effective manner, the EU ETS sets up a cap-and-trade system for nearly 10,000 factories, oil refineries, electricity utilities, and more. The ETS market allows buyers the flexibility to find low-cost carbon emissions from around the world. Estimates suggest that a well-functioning market would cut the costs of reaching the Kyoto targets by between 50–80 per cent (see Chapter 9). The main criticism is that the EU ETS caps were set in too loose a fashion in Phases I and II to induce a significant reduction in carbon emissions. The counter-argument is that Phases I and II helped the EU define how the system would work—better emissions data, better monitoring, and creating a positive price on carbon emissions. Phase III begins in 2013, with the stated goal of reducing carbon emissions in the EU by 21 per cent from 2005 levels (see Parker, 2010).

Summary

Over millennia, humans increased their life expectancy by a few years. About 200 years ago, something changed, and since then Western culture has witnessed a thirty-year increase in our longevity. Economists do not see this as a coincidence. In 1776, Adam Smith published his classic work *The Wealth of Nations*, which explained the power of the market to create wealth through trade. Economists argue that understanding how markets collect, codify, and disseminate diffuse information has helped to create the social order to improve the quality and length of life in our modern world for many people.

In this chapter, we have examined how markets can work against and for the environment and natural resources. Markets are a process of discovery. Markets allow us to create wealth, which in turn allows us to create more health. And even when one market fails, a new market can be constructed to manage the environment. Markets do not substitute for good environmental policy; rather, they can be a good tool to promote more protection for less wealth. Markets can make good environmental policy better by allowing for the flexibility to protect valuable resources cost-effectively. Remember: markets work for us, and not the other way around. Identifying if and how markets can be created or corrected is a major task for all of us who are interested in providing more environmental protection at less cost.

Tutorial Questions

2.1 Define Pareto efficiency.

2.2 Explain the four conditions that must hold for the existence of a well-defined property rights system, and address why all four matter.

2.3 Why do economists promote the idea of creating markets for environmental protection?

2.4 What is a public good and why are public goods considered a market failure?

2.5 Explain the idea behind the phrase the 'tragedy of the commons'.

2.6 Explain why moral hazard and adverse selection are market failures?

2.7 How can government help solve the problems of hidden information?

2.8 Explain how Pigovian taxes work to control pollution.

2.9 How do tradable pollution permits work in theory and in practice?

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